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DYNAMIC DEFORMATION AND FRACTURE OF PLAIN AND FILLED ELASTOMERS--ETC(U)

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DYNAMIC DEFORMATION AND FRACTURE OF PLAIN AND FILLED ELASTOMERS

Final Report

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September 1981

By: Y. M. Gupta [redacted] W. J. Murri

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Prepared for:

OFFICE OF NAVAL RESEARCH
Power Program
Arlington, VA 22217

Attention: Dr. R. S. Miller (Code 473)

ONR Contract N00014-78-C-0549

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To quantify the high strain-rate mechanical response of plain Solithane, compression, shear, and tension experiments were performed under impact loading (microsecond time scales). Compression and tension measurements were carried out for filled Solithane containing 56.5 wt% of glass beads. The results show that the compression response (uniaxial strain) of plain Solithane is dominated by the mean stress-volume relation. The bulk modulus under impact loading is considerably higher than that determined from static

Abstract (concluded)

measurements in the glassy state. The filled Solithane compression response can be approximated by a simple mixture theory using the Hugoniots of plain Solithane and glass.

Shear wave measurements in the plain Solithane were used to determine the shear modulus and the shear stress-strain response at several shock compressions. The shear modulus varied between 3 and 9 kbar for compressive stresses ranging between 2 and 14 kbar. With increasing compression, the dynamic shear modulus increases sharply in contrast to quasi-static measurements under pressure. The dynamic shear stress-strain curves show a decreasing modulus with increasing strain and suggest an elastic-plastic response with yield strength increasing from 0.12 to 0.25 kbar with increasing pressure for the compressive stress range investigated. This direct determination of the shear response will be very valuable for development of constitutive models because this information cannot be obtained from compression data.

Tension experiments on plain and filled Solithane show elastic-brittle fracture response for both materials. However, the threshold between no damage and full spall is considerably sharper for the filled Solithane. The sharper threshold is caused by the rapid linking of closely spaced cracks nucleated at the filler-matrix interface. The tensile damage is very localized, and the location can be predicted by simple wave interactions. Two experimental methods were attempted to quantify the fracture response on the microsecond time scales and to measure the fracture damage in the recovered specimens. These measurements have given encouraging results, but more work is needed before they can be used successfully. Because of a lack of quantitative measurements in previous studies, these measurements should be pursued in future work.

TECHNICAL SUMMARY

The objectives of the work presented in this report were to directly determine the response of elastomers to compression, shear, and tension under dynamic loading conditions. These objectives have generally been met and a good start has been made in making these measurements. The main results are summarized below.

The compression results in plain Solithane are dominated by the mean stress-volume response. The bulk modulus under impact conditions is considerably higher than that determined from static hydrostatic loading. The response of the filled Solithane is stiffer and to a good approximation can be predicted by a simple mixture theory using the Hugoniots of glass and plain Solithane. The longitudinal modulus measured in impact experiments is similar to ultrasonic values and is bounded by the very high frequency (10^{10} Hz) and quasi-static measurements.

Shear wave profiles have been measured in plain Solithane at several compressions. The wave profiles are dispersive. With increasing compression, the dispersion decreases, but attenuation increases. The shear modulus values range between 3 and 9 kbar for compressive stresses ranging between 2 and 14 kbar. Unlike the quasi-static shear modulus, the dynamic data suggest a rapid increase with compression at higher stresses. High strain-rate, shear stress-strain curves have been obtained at three compression levels. The overall features are similar to quasi-static torsion measurements in glassy polymers under pressure. The stress-strain response is typical of an elastic-plastic solid with yield strength varying between 0.12 and 0.25 kbar for a volume compression ranging from 6% to 20%. The compression and shear data can be used to develop a realistic constitutive model at high strain rates.

Tension recovery experiments on plain and filled Solithane show an elastic-brittle response for both materials. The damage is quite localized, and the location can be predicted from simple wave interactions. Although the recovery experiments provide a good description of the fracture damage, it is difficult to quantify these experiments. Two types of measurements to quantify tensile fracture were attempted in the present work: (1) pull-back signal measurements to characterize the tensile strength and fracture kinetics on the microsecond time scale and (2) surface area measurements on recovered specimens using the BET method. Both of these measurements have given encouraging results, but further development is needed before they can be used successfully.

Future work should focus on the following topics:

(1) Measurement of shear response above 15-kbar compression stress.

(2) Measurement of shear response for filled Solithane to determine if these measurements can be correlated with the data for plain Solithane.

(3) Attempts to quantify the tensile fracture damage.

(4) Preliminary development of a dynamic constitutive model.

PUBLICATIONS AND PRESENTATIONS

1. Y. M. Gupta and W. J. Murri, "Response of a Plain and Filled Elastomer (Solithane 113) to High Strain-Rate Compression, Shear, and Tension Loading," Technical Report submitted to ONR under Contract N00014-78-C-0549, SRI International, Menlo Park, CA (January 1981).

2. Y. M. Gupta, W. J. Murri, and D. Henley, "Large Amplitude Compression and Shear Wave Propagation in an Elastomer," paper presented at the Topical Conference on Shock Waves in Condensed Matter held at SRI International Menlo Park, CA (June 1981); Bull. Am. Phys. Soc. 26, 657 (1981).

3. Y. M. Gupta and W. J. Murri, "High Strain Rate Fracture of Unfilled and Filled Elastomers," Bull. Am. Phys. Soc. 26 (March 1981).

4. Y. M. Gupta, "High Strain-Rate Shear Response of an Elastomer" (manuscript in preparation).

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